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FORMULATION OF MATHEMATICAL MODEL FOR PROCESSING TIME AND ENERGY CONSUMPTION FOR THE INVESTIGATION OF SPINNING MACHINE PROCESS BY USING FIELD DATA BASED MODEL TECHNIQUE

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ABSTRACT

In this research paper mathematical model is formed for the responses processing time and energy consumption of spinning machine during the process. Recognition of causes followed by dimensional analysis is carried out. Observations noted on different loading conditions. Mathematical models for processing time and energy consumption formed by FDBM methodology.

KEYWORDS: Mathematical Model, FDBM, Processing Time & Energy Consumption

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Original Article

1. INTRODUCTION

Mathematical Model for any kind of investigation represents one kind of predictive model. Here in this research paper study of spinning process is carried out. As far as the mathematical model is concerned, various independent variables are found out. Field Data Based Modelling is the process of representing any mechanical system with the help of some equations. Mathematical modelling plays a vital role in analyzing the physical nature of the system. System is divided into two physical or experimental and another one is a abstract model or a model which can be just created. In abstract model one can simulate and in mathematical model one will get analytical or simulated result. In case of simulated results one can compare these with actual system results. It reflects whether the system is preserving the actual behavior of the system or not. Mathematical models are having huge applications in almost all sectors like engineering and sciences.

2. SPINNING PROCESS

Twisting yarn from plants or animal fibres was taken from ancient age. Around 500 b. c. spinning process generated in India. Today factories have fully automated spinning machines that works on a same principles of spinning wheels. Spinning is the process of drawing yarn from sliver (roving) which comes out from carding process. In spinning twisting of yarn is done. Roving is 3 and half to 16 times thinner than sliver. Spinning machine which is used in this research is shown below:



Figure 1: Experimental Setup

3. FORMULATION OF MODEL FDBM METHODOLOGY

The following methodology is adopted for this research

- Spinning machine and spinning process study
- Credentials of independent and dependent variables
- Observations on actual spinning machine (8 spindle solar powered charkha)
- Measurement method and instruments used
- Selection of FDBM methodology
- Results analysis

3.1 Spinning Machine and Spinning Process Study

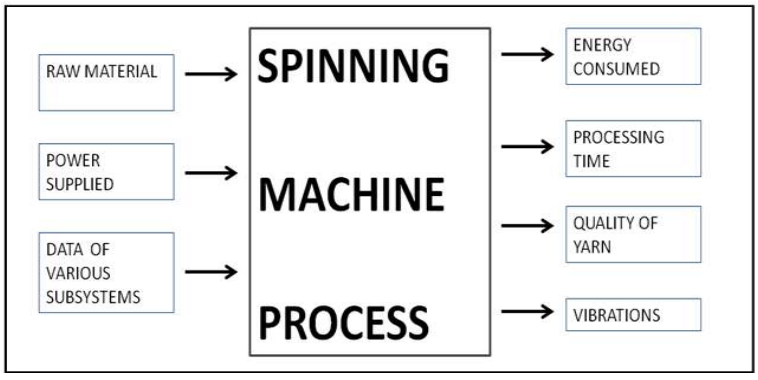


Figure 2: Spinning Machine System

From figure 2 it is clear the main inputs are divided into raw material, power supplied and the data collected from various subsystems of machine. These inputs undergoes through spinning machine process. Outputs displayed in figure 2 for research are energy consumed, processing time, quality of yarn and vibrations. But as far as this research paper is concerned only two output variable are chosen and those are processing time and energy consumption.

3.2 Credentials of Independent and Dependent Variables

Table 1: Independent and Dependent Variables

Sr. No.	Variables	Type	Symbol	Unit	Dimensional formula
1	Motor speed	I	Nm	rpm	T^{-1}
2	Speed of main shaft	I	Ns	rpm	T^{-1}
3	Diameter of main shaft	I	Ds	mm	L^1
4	Length of shaft	I	Ls	mm	L^1
5	material density of shaft	I	Rhos	gm/mm^3	M^1L^3
6	centre distance between machine pulleys	I	Cp1-Cp8	mm	L^1
7	material density of machine pulleys	I	rhop	gm/mm^3	M^1L^3
8	Volume of machine pulley	I	Volp	mm^3	L^3
9	Machine pulley diameter	I	Dp1-Dp9	mm	L^1
10	Mean radius of bearing cap	I	Rmb	mm	L^1
11	Thickness of bearing cap	I	Tb	mm	L^1
12	Width of bearing cap	I	Bbcap	mm	L^1
13	Material density of bearing cap	I	rhobcap	gm/mm^3	M^1L^3
14	Modulus of elasticity of bearing cap material	I	Ebcap	$gm/mm\ s^2$	$M^1L^{-1}T^{-2}$
15	Inner diameter of bearing	I	dbi	mm	L^1
16	Outer diameter of bearing	I	dbo	mm	L^1
17	bearing width	I	Bb	mm	L^1
18	Material density of gear	I	rho g	gm/mm^3	M^1L^3
19	Gear ratio	I	G	Dimensionless	Dimensionless
20	Gap between feed rollers	I	gf1-gf2	mm	L^1
21	Length of feed rollers	I	Lf1-Lf3	mm	L^1
22	Diameter of feed rollers	I	Df1-Df3	mm	L^1
23	Material density of top arm(rubber)	I	rho t	gm/mm^3	M^1L^3
24	speed of spindles	I	Nsp	rpm	T^{-1}
25	Length of spindles	I	Lsp	mm	L^1
26	number of spindles	I	n	Dimensionless	Dimensionless
27	Length of thread from machine pulley to spind;e through tension pulley	I	Lthr	mm	L^1
28	Length of oscilating roller follower from pin joint to roller	I	Lorf p	mm	L^1
29	Length of oscilating roller follower from pin joint to cam centre	I	Lorf c	mm	L^1
30	Material density of roller	I	rho rolf	gm/mm^3	M^1L^3
31	Weight of cam	I	Wcam	gm	M^1
32	Length of lever from roller to plate of spindle	I	Llev	mm	L^1
33	Moisture content in roving	I	Wmro	gm	M^1
34	Quantity of roving processed in certain time	I	Qnrov	gm	M^1
35	Thickness of follower lever	I	Tlev	mm	L^1
36	Total quantity of roving	I	Qtyr	gm	M^1
37	Acceleration due to gravity	I	g	mm/s^2	L^1T^{-2}
39	Processing time	D	PT	sec	T^1
40	Energy consumed	D	EC	$gm\text{-}mm^2/s^2$	$M^1L^2T^{-2}$

3.2.1 Reduction of Variables

All these 39 independent variables are reduced down into 4 pie – terms by using Buckingham's pie theorem, which are shown in Table 2and Table 3

Table 2: Reduction of Independent Variables

Input pie Terms			
π_1	π_2	π_3	π_4
$\frac{N_s}{N_{sp}}$	$\frac{d_s * C_{p1} - C_{p8} * T_b * d_{bi} * B_b * L_{f1} - L_{f3} * L_{sp} * L_{orfp} * L_{lev})}{(L_s * D_{p1} - D_{p9} * B_{bcap} * d_{bo} * g_{f1} - g_{f3} * D_{f1} - D_{f3} * L_{thr} * L_{orfc} * t_{lev})}$	$\frac{\rho_g * \rho_{rolf} * Vol_p * W_{cam} * Q_{nrov}}{\rho_t * \rho_{bcap} * r_{mb} * W_{mrov} * Q_{tyr}}$	$\frac{E_{bcap} * g * G * n}{\rho_{bcap} * (N_m^4 * R_{mb}^3}$

Table 3: Reduction of Dependent Variables

Output pie Terms	
πd_{10}	πd_{11}
$Y_2 . N_m$	$\frac{Y_3}{\rho_{bcap} {N_m}^2 {R_{mb}}^5}$

3.3 Observations on Actual Spinning Machine (8 Spindle Solar Powered Charkha)

There are total 500 observations taken on 8 spindle charkha which is solar powered.

3.4 Measurement Method and Instruments Used

For the dependent variable processing time, stop watch is used and readings are taken in equal interval (5 min, 10 min, 15 min, etc)

For dependent variable Energy consumption, voltmeter is used.

Energy consumption is calculated by the following formula:

Energy consumption = Voltage x Current consumed

= 12V x 3.35 A

= 40.2 w / hr

∴ Energy consumption per day =40.2 x 8 = 321.6 whr

3.5 Selection of FDBM Methodology

For the whole analysis it has been decided to go for Field Data Based Mathematical Modeling. In this methodology, experimentation is carried out on the actual machine which is located at Wardha.

For processing time, π_{d10} is decided. π_1, π_2, π_3, and $\pi_4$areindependent pie – terms. π_{d10} is the function of all independent π_1, π_2, π_3, and $\pi_4$terms.

$\therefore \pi_{d10} = f(\pi_1, \pi_2, \pi_3, \pi_4)$

The model representing the behavior of dependent pie term π_{d1} with respect to various independent pie terms can be obtained as under.

$$\pi_{d10} = k_1 \times \pi_1^a \times \pi_2^b \times \pi_3^c \times \pi_4^d \quad (1)$$

The values of exponent are a, b, c, d, are formed independently at a time, on the basic of data collected in the course of classical experimentation. Where K is curve fitting constant and a, b, c, d are indices.

By taking log of both sides one can get matrix in the form of[Y]=[X] x[a]

Now, for obtaining model for processing time response (Y_{10}), the equations in matrix form can be presented as:

$$\begin{pmatrix} 2398.89 \\ -6181.37 \\ -2906.38 \\ -6399.80 \\ -24804.54 \end{pmatrix} = \begin{pmatrix} 500.00 & -1288.39 & -605.77 & -1334.02 & -5170.01 \\ -1288.39 & 3320.17 & 1560.95 & 3437.78 & 13321.95 \\ -605.77 & 1560.95 & 733.93 & 1616.24 & 6263.72 \\ -1334.02 & 3437.78 & 1616.24 & 3572.03 & 13793.61 \\ -5170.01 & 13321.95 & 6263.72 & 13793.61 & 53466.66 \end{pmatrix} \begin{pmatrix} K \\ a \\ b \\ c \\ d \end{pmatrix}$$

Now the value of the indices could be obtained by performing matrix operation using MATLAB software.

The values of the indices are:

K = 1030.62; a = 0.2218; b = -2.1761; c = 0.0403; d = 0.0167;

Then after substituting the values of the indices, one get the equation for the corresponding models as under:

$$\boldsymbol{\pi_{d10} = 1030.6 \times \pi_1^{0.22} \times \pi_2^{-2.17} \times \pi_3^{0.0403} \times \pi_4^{0.016}} \quad \textbf{(2)}$$

Similarly,

Model for Energy consumption is formed

$$\boldsymbol{\pi_{d11} = 0.0014 \times \pi_1^{0.97} \times \pi_2^{1.31} \times \pi_3^{0.042} \times \pi_4^{0.021}} \quad \textbf{(3)}$$

3.6 Results Analysis

3.6.1 For Model (Y_{10}) Processing Time

It is observed from the equation (2) influence of indices of independent π- terms on response variable for Processing time (Y_{10}) as a response variable. The following conclusions become visible to be reasonable by the above model.

- The absolute index of π_2 is high i. e. 2.17. Hence π_2, the term related to the geometric dimensions influences more in the model. Negative sign indicates that πd_{10} increases as this π term decreases and vice versa.
- π_4 is having less index i. e. 0.016. It means π_4- term associated to miscellaneous parameters which is having less effect on π_4 - term in the model. Positive sign indicates that πd_{10} increases as this π_4 - term increases and vice versa, but has the lesser effect on the dependent π - term.
- The sequence of direct effect of other π terms nearby in this model are π_1, π_3 having indices of 0.22 and 0.0403 respectively. Both indices are positive which indicates πd_{10} increases as these π terms increases or otherwise.
- The curve fitting constant is 1030.6. This curve fitting constant represents combined result of certain beyond measure parameters which have influence on the dependent π term.

3.6.2 For Model (Y_{11}) Energy Consumption

It is observed from the equation (3) effect of indices of independent π - terms on response variable for Energy Consumption (Y_{11}) as a response variable. The following conclusions are as follows:

- The index of π_2 was the high i. e. 1.31. Hence $\pi_2$is related to the geometric dimensions which influences π - term in the model. Positive value of this index indicates that πd_{11} increases on the increase of π_2 . term and vice versa.
- The index of $\pi_4$is low i. e. 0.021. It means π_4 - term related to assorted parameters having less influencing term in

the model. Positive value indicates that πd_{11} increases as π_4 increases or vice versa.

- The sequence of direct influence of other π terms present in this model are π_1, π_3 having indices of 0.97 and 0.042 respectively. The value of both the indices are positive indicating πd_{11} increases as these π terms increases or vice versa.
- The curve fitting constant is 0.0014. This curve fitting constant represents combined effect of certain beyond measure parameters which have influence on the dependent π term.

4. CONCLUSIONS

Here it is observed that, exponential form of the model by using FDBM is very much effective tool for the formation of mathematical model. From these it reflects that out of so many causes which factor is most influencing on dependent parameter like here researcher used processing time and energy consumption. After the huge study of these model, it is concluded that whatever the results came out, that should be tested by experimental model.

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